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JOURNAL
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A STUDY OF THE ACTION OF VARIOUS DIURETICS IN URANIUM NEPHRITIS[1]

By Wm. deB. MacNider.

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In a recent anatomical study (1) of the nephritis produced in the dog by the use of various nephrotoxic substances it has been shown that these substances vary to some extent in the degree of their selective affinity for the different kidney tissues. Arsenic, for example, has a striking affinity for the blood vessel tissue of the kidney; while potassium dichromate causes an involvement of the epithelial element of the kidney much earlier than does any of the usually employed nephrotoxic substances.

Uranium nitrate, a substance which has frequently been employed to produce experimentally a nephritis, in its avidity for the different tissues of the kidney, is not so selective in its action as are the poisons just mentioned.

If uranium be given in large doses subcutaneously, or if smaller quantities be used and the nephritis be allowed to persist for some days, the nephritis which it induces with such a technique is more tubular than vascular. If, on the other hand, small quantities are employed, 5 to 10 mgs. per animal, and if the nephritis be terminated early, the reaction on the part of the

[1] Presented in abstract before the Society for Pharmacology and Experimental Therapeutics, Baltimore, December 27, 1911. Reprinted from *The Journal of Pharmacology and Experimental Therapeutics*, Vol. III, No. 4, March, 1912.

kidney is largely vascular. We possess, therefore, in uranium a nephrotoxic substance which, when appropriately administered, is competent to produce the two main types of nephritis. For this reason uranium was the nephrotoxic substance selected to use in the production of nephritides of different severity, in which one or both elements of the kidney concerned in the formation of urine were functionating pathologically.

By the use of such a substance which produces primarily a vascular, and later a tubular nephritis, it was hoped that by studying the physiological response of the kidney at these stages of its pathological reaction, it might be determined which element of the kidney in a nephritis was most concerned in determining the quantitative output of urine. With this object in view in this study diuretics have been employed which effect both the vascular and the epithelial elements of the kidney.

In the anatomical study of experimental nephritis which has been previously referred to, the nephrotoxic substances employed were potassium dichromate, sodium arsenate, cantharidin and uranium nitrate. During the course of this investigation it was noted that there existed a fairly clear cut correllation between the degree of epithelial involvement in a given nephritis and the total output of urine; whereas, on the other hand, no such histological correllation could be made, within certain limitations, between the severity of the vascular pathology and the output of urine. For example, a nephritic animal with a normal urine flow, or a polyuria, would show a vascular reaction which histologically would be similar to the vascular pathology in an anuric animal. The associated epithelial reaction in such stages of a nephritis differed very widely. In the early nephritides with a normal output of urine, or a polyuria, the epithelial involvement was slight or absent. In some of the experiments, especially those conducted with uranium, the epithelium appeared to have undergone a shrinkage. In the later stages of the nephritis when the output of urine had been reduced or an anuria had developed, the epithelium, and especially that of the convoluted tubules invariably showed marked alterations. The epithelial changes varied with the severity of the nephritis.

The earlier degenerations consisted in cloudy swelling and vacuolation, while the later changes were principally an epithelial desquamation, usually preceded by necrosis.

In these late nephritides the swelling of the epithelium was frequently decidedly noticeable and was sufficient either greatly to encroach upon or completely occlude the lumen of the tubules.

The present physiological study of the nephritic kidney has been undertaken to determine, if possible, the part played by the vascular and by the epithelial pathology of the kidney in influencing the output of urine, and to determine whether or not the vascular mechanism of the kidney is physiologically responsive in a nephritis in which there is evidence of epithelial involvement and but little histological evidence of vascular injury.

Review of Literature

The two most important recent contributions to the study of acute experimental nephritis are those by Schlayer (2) and Hedinger and by Pearce (3), Hill and Eisenbrey.

These investigations were conducted with the same general object in view and are principally concerned with the physiological response of the nephritic kidney.

Schlayer and Hedinger studied the vascular reaction of the kidney in both the glomerular and the tubular types of nephritis. For their studies in the vascular type of nephritis they employed as kidney poisons, cantharidin, arsenic and diphtheria toxin, and for the tubular type potassium chromate and corrosive sublimate.

The investigation by Pearce, Hill and Eisenbrey was also principally concerned with the vascular reaction in acute nephritis. The authors were able to distinguish types of nephritis in which either the tubular or the vascular changes predominated. They were not able to conclude, however, that a given poison produced an exclusively tubular or vascular injury. Potassium chromate, corrosive sublimate and uranium nitrate, caused extensive tubular injury and in the early stages of the nephritis showed no evidence of vascular injury except physiologically. When physiological methods were employed they were able to demonstrate in the early stages of the nephritis

an exaggerated contraction and dilatation of the vessels and also an increased diuresis. Arsenic and cantharidin acted as vascular poisons and produced but little injury to the tubules. Both of these poisons tended to cause an anuria which was characterized by minimal contraction and dilatation of the renal vessels and little or no flow of urine. Finally, in this investigation two types of late tubular nephritis are described: one anuric and accompanied by gastro-intestinal symptoms; and the other polyuric until the time of anesthesia.

In addition to these two investigations which are principally concerned with the physiological response of the kidney, pathological studies of the kidney in a uranium nephritis have been made by several investigators.

Heineke and Myerstein (4) were able to demonstrate a marked vascular disturbance in the kidney from uranium in addition to a pronounced action on the renal epithelium; while Dickson (5) in an extensive series of experiments in which the guinea pig was the animal employed came to the same conclusions.

Christian (6) in his work on uranium nephritis in which the vascular pathology was studied, described as developing in the capillaries of the glomerulus, oval or irregular homogeneous droplets 0.5 to 4 microns in diameter. Similar structures have been observed in several of the experiments in the series of animals which will be presented in this study.

The work of Schirokauer (7) on the uranium nephritis of rabbits is of special interest on account of the associated anasarca.

DISCUSSION OF THE TECHNIQUE EMPLOYED IN THE EXPERIMENTS

In conducting the experiments the dog was the animal constantly employed. A total of twenty-three animals were used. The animals were free from disease and their general nutrition was apparently normal.

For three days prior to the experiments the animals were kept in metabolism cages, fed on beef and hard bread and given once a day by stomach tube a known and constant quantity of water. The quantity of water varied with the size of the ani-

mal. During the period of preliminary observation the urine was collected daily, measured and studied qualitatively and microscopically. The existence of a naturally acquired nephritis was excluded. Two of the animals showed the presence of albumen and erythrocytes in the urine but no casts.

At the end of three or four days, after the preliminary data had been obtained, the animals were given from 5 to 10 mgs. of uranium nitrate subcutaneously. The frequency with which the injections were repeated was determined by the severity of the nephritis produced by a given injection and by the stage of the nephritis that was desired in which to study the action of the different diuretic substances. Such a method of regulating the quantity of nephrotoxic substance is more accurate, so far as the reaction on the part of the kidney is concerned, than can be obtained by using a constant quantity of the kidney poison per kilogram of body weight, since different animals vary very greatly in their response to the same quantity of the poison.

Usually within twelve or twenty-four hours after the initial injection of uranium the animals had developed a well-marked nephritis.

Occasionally on the first day of the nephritis, and almost invariably by the second day, the animals developed a pronounced glycosuria. The quantitative output of albumen was not determined. Quantitative sugar determinations were made with both Fehling's and Purdy's quantitative reagents. These determinations showed that the output of sugar in a twenty-four hour specimen of urine varied from 0.25 to 3.22 per cent.

After the production of the nephritis the animals were anesthetized with either morphine-ether or Gréhant's anesthetic.[1]

The following operative technique was constantly employed.

A tracheal canula was tied in place and connected with the ether bottle to be used in case additional anesthetic was necessary during the experiment.

[1] *Gréhant's Anesthetic.* The animal is given ¼ cc. per kilogram of a 4 per cent solution of morphine. This is followed in half an hour by 10 cc. per kilogram of the following mixture: Chloroform, 50 cc.; alcohol and water, each 500 cc.

The carotid pressure was recorded in the usual way, and a relative idea of the heart volume was obtained along with the pressure tracing by means of a Hürthle manometer.

The left kidney was surrounded by a rubber bag filled with water, and the kidney with its surrounding water cushion placed in a copper oncometer. The oncometer communicated by means of a rubber tube with a water manometer which registered on an arbitrary scale graduated in millimeters the increase or the decrease in the volume of the organ.

Into each ureter was placed a ureter canula. Observations of the urine flow were made only from the right kidney, on account of the fact that the flow from the left kidney was possibly influenced by the mechanical disturbance necessarily associated with the use of the oncometer.

The various diuretic solutions were given intravaenously through the femoral vein, due care being taken of their temperature.

The experiments were of such a nature that they would necessarily require considerable time for consecutive observations of the action of the different diuretics. On this account it seemed advisable to employ some method to maintain a fairly constant body temperature. For this purpose a copper water box was used, similar to the ones employed in Sollmann's laboratory. The upper surface of the box is concave and holds a wooden rack in which the animal is placed. With such an apparatus the animal's body temperature can be fairly accurately maintained.

At the termination of the experiments, the kidneys were at once removed and tissue fixed for microscopic study in both corrosive-acetic and in formaline.

Five of the twenty-three animals employed in this investigation were either purposely or accidentally killed before or at the commencement of the anesthetic. Kidney tissue from these animals was fixed for histological study.

In the remaining eighteen animals the physiological response of the nephritic kidney was studied under the influence of:

Caffeine.....1-2 cc. of a 1 per cent solution per kilogram
Theobromine....1-2 cc. of a 1 per cent solution per kilogram
Digitalin.....1 mg. per kilogram
Sodium chloride solution....0.9 per cent, 10 cc. per kilogram

COURSE OF THE EXPERIMENTS

The average daily output of urine of each animal was determined at the end of the third day, during which time the preliminary observations were being made. Following the injection of uranium the daily output of urine was ascertained and compared with the average daily output by the animal prior to the use of uranium.

Three of the animals were used experimentally after they had developed a nephritis but before the development of a glycosuria. The daily output of urine by these nephritic and non-glycosuric animals showed a moderate increase as follows. The urine from the different animals increased respectively from 278 to 318 cc., from 392 to 440 cc. and from 386 to 358 cc. The urine showed qualitatively a pronounced reaction for albumen, and microscopically hyaline and granular casts and erythrocytes.

The remaining animals were used experimentally after the development of a glycosuria. In each instance, with the development of a glycosuria the output of urine at once enormously increased. For example, in experiment 1, in which the animal was receiving daily 350 cc. of water, the average daily output of urine for three days prior to the uranium was 385 cc., while with the development of a nephritis and an accompanying glycosuria the urine increased on the first day to 620 cc. and on the second day to 750 cc.

Again, in experiment 8, in which the animal was receiving 500 cc. of water daily, the average output of urine prior to the uranium was 513 cc., while following the uranium with the development of a nephritis and a glycosuria the output of urine increased to 1310 cc.

This increase in the output of urine was not an occasional occurrence, but it developed in each animal that was allowed a sufficient time to develop a glycosuria. These polyuric and nephritic animals were anesthetized by one of the methods pre-

viously mentioned. Within thirty-four minutes to an hour and a half after the commencement of the anesthetic, the output of urine from these excessively diuretic animals was either very greatly reduced, reduced to a condition bordering on an anuria, or an anuria had developed, which in six of the animals persisted throughout the experiment, uninfluenced by the diuretics which were employed.

This pronounced reduction in the output of urine after the anesthetic is equally as striking as is the increase in the output of urine after the animals have developed a glycosuria.

Experiment 20 is used to illustrate these observations. The animal was receiving 500 cc. of water daily. The average output of urine for the three days prior to the uranium was 464 cc. The animal was given subcutaneously one injection of uranium of 10 mgs. The animal rapidly developed a nephritis and a glycosuria, and the urine increased to 1018 cc. At the time of the experiment 294 cc. of this urine was found in the bladder, which shows quite clearly that the animal was diuretic until the time of anesthesia. The experiment lasted four hours and during this time the animal was in a perfectly satisfactory physiological condition. The general blood pressure varied between 93 and 108 mm. of mercury and the renal vessels were physiologically responsive to caffeine, theobromine and 0.9 per cent salt. Not a drop of urine was voided.

This experiment, associated as it is with others which give identically the same results, shows a definite relation between the polyuria and the development of glycosuria. Secondly, it shows an equally intimate connection between the use of an anesthetic and the development of an anuria. The polyuria in uranium nephritis and the influence of the anesthetic in reducing the output of urine has been observed by both Schlayer (2) and Pearce (3). Pearce attributes the anuria to a "decreased glomerular permeability" and makes a similar suggestion to interpret the results obtained by Schlayer. So far as I have been able to learn these authors make no note of the association of the polyuria with the onset of the glycosuria.

The effect of diuretics in uranium nephritis

To facilitate the study of the effect of the different diuretics the experiments have been classified into groups, *e. g.,* the Anuric, Practically Anuric and Diuretic Groups.

Anuric group

Six experiments are included in this group. In all six of the animals caffeine, theobromine, and digitalin were employed as diuretics and in four of the animals 0.9 per cent salt was also used. None of these agents had any effect in reëstablishing a flow of urine. This failure cannot be attributed to either a failure on the part of the diuretics to increase and maintain an adequately high general blood pressure for urine secretion, or to a failure in the vascular response of the kidney. The following experiment will serve well to illustrate these points:

Experiment 23. The animal's general blood pressure at the commencement of the experiment was 104 mm. of mercury and at the termination 107 mm. Caffeine produced a rise in arterial pressure of 4 mm. of mercury and a rise in the oncometer of 27 mm. (water manometer). Theobromine produced a rise of 7 mm. in general pressure, and a rise in oncometer pressure of 59 mm., digitalin a rise of 18 mm. in arterial pressure and 20 mm. in oncometer pressure, while 0.9 per cent salt caused no rise in general blood pressure, but a rise of 15 mm. in oncometer pressure. The animal remained anuric throughout the experiment.

Practically Anuric group

Falling in this group are experiments 6 and 11. They represent animals which are not absolutely anuric but which show a gradual decline in the flow of urine which is but slightly influenced by the diuretics.

The first animal of this series, experiment 6, prior to the anesthetic had an output of urine of 810 cc. Following the anesthetic an anuria developed for two hours, although during this time a rise of blood pressure of 14 mm. of mercury and of oncometer pressure of 12 mm. of water was obtained from caffeine and a rise of 10 mm. in general pressure and of 12 mm.

in oncometer pressure from theobromine. During the last half hour of the experiment, under the effect of 0.9 per cent salt the arterial pressure rose 17 mm. and the oncometer pressure 20 mm. The urine filled the ureter canula and a few drops were discharged into the receiving flask.

Experiment 11 followed the same general course. Prior to the anesthetic the animal was highly polyuric. Following the anesthetic the output of urine for the first half hour period was 2 cc. The urine flow then decreased, although the animal showed the usual physiological response to caffeine and theobromine. During the final half hour period of the experiment the flow of urine had been reduced to two drops. The experiment demonstrates a continuance of those changes, whatever they may be, which lead to an anuria, and which commence with the administration of the anesthetic, and in this instance have progressed, uninfluenced by the employment of diuretics.

Diuretic group

In the animals classified as diuretic, the term is used relatively. With few exceptions these experiments were terminated artificially during a period of diuresis. Such a termination does not exclude the possibility of the animal later becoming anuric as was illustrated in the previously described experiment.

The following experiments are representative of this group:

Experiment 16. The animal had a pronounced nephritis, was polyuric and had developed a glycosuria. Following Grêhant's anesthetic the animal became anuric for fotry-five minutes. Following the use of caffeine, with a rise of arterial pressure of 5 mm. of mercury and of oncometer pressure of 8 mm. the urine flow was reëstablished and during the half hour period following the use of caffeine the flow of urine was 1.5 cc. Under theobromine without a rise in arterial pressure but with a rise in oncometer pressure of 4 mm., the flow of urine increased to 3 cc. in a half hour period. With digitalin which produced a rise in arterial pressure of 10 mm. and in oncometer pressure of 8 mm. the urine flow increased to 3.3 cc. in a half hour interval.

In three of the experiments of this series 0.9 per cent salt was used. With the salt solution the greatest degree of diuresis was produced and this diuretic effect from the salt was more constant than that from the other diuretics in this type of nephritis.

In experiment 19, the flow of urine in the half hour period prior to the use of salt solution was 0.9 cc. Following the salt with a rise in arterial pressure of 14 mm. and in oncometer pressure of 49 mm. the urine increased 1.7 cc.

In experiment 17 with a flow of urine of 1.6 cc.—prior to the use of salt solution, following its use the urine increased to 4.6 cc. The oncometer pressure rose 18 mm. and the general pressure 6 mm.

The following deductions concerning the diuretic value of the different substances employed in these groups of experiments are as follows:

1. In the anuric group, caffeine, theobromine, digitalin and 0.9 per cent salt solution have no effect in reëstablishing the flow of urine. Their failure does not depend upon their inability to raise and maintain a sufficiently high general blood pressure to produce diuresis.

2. The inactivity of these substances is not due to their inability to influence the local renal circulation, for the physiological vascular response of the renal vessels as indicated by the oncometer readings is normal or hyperactive.

3. In the group of experiments classified as practically anuric the same deductions concerning the inefficiency of the diuretics are allowable.

4. In addition to these deductions relative to the effect of the diuretics, this group also shows that the quantity of urine may not only not be increased by the diuretics, but that the output of urine may progressively decrease, even though the general blood pressure readings and oncometer readings show the usual response.

5. In the diuretic group in which the animals show the same physiological response to the diuretics as was shown by the animals in the anuric and practically anuric groups—the sub-

stances effect a diuretic action. Salt solution, 0.9 per cent, shows a more constant diuretic effect, and the increase in the flow of urine from the salt is more pronounced than it is from the other substances.

THE RENAL PATHOLOGY

Five of the animals used in this investgiation were killed either prior to the anesthetic or during its administration. Four of these animals had an early uranium nephritis, were markedly polyuric and had a glycosuria. The fifth animal had a late uranium nephritis, was glycosuric but was not polyuric. The output of urine was reduced below the normal.

In the four early nephritides the vascular pathology of the kidney was much more pronounced than was the epithelial pathology, while in the fifth animal with a late uranium nephritis in which the output of urine had been reduced below the normal, the epithelial pathology predominated. The vascular pathology in the early nephritides consisted primarily of an acute engorgement of the glomerular capillaries. The hyperaemic capillary tufts usually filled the space enclosed by Bowman's membrane and frequently this structure gave the appearance of being distended by the enclosed capillaries. The endothelial nuclei of the capillaries and of the capsular membrane showed no degeneration but were unusually prominent. Within the capilliaries the vacuoles first described by Christian (6) were observed in two of the kidneys.

The intertubular vessels showed the same engorgement with an occasional intertubular exudate containing a few erythrocytes.

With this pronounced vascular reaction on the part of the kidney the epithelial pathology was remarkably slight. The epithelium had not degenerated, it stained well and showed no encroachment upon the lumen of the tubules. (Figs. I and II.)

A comparison of the epithelial changes in these animals, with the epithelial changes in those animals having a complete anuria is as striking as is the difference in the output of urine by the two groups of animals before and after the administration of an anesthetic.

Four of the anuric animals were in an early stage of uranium nephritis, the stage which has just been described as existing in the animals killed before the administration of an anesthetic. In these animals with an early uranium nephritis which were polyuric and glycosuric, and which following the anesthetic became anuric, the vascular pathology was histologically similar to the vascular pathology noted in those animals that had not been subjected to the effect of an anesthetic. The epithelial pathology in these two groups of animals shows, however, a well marked difference. The epithelium in the anuric animals is very greatly swollen and is usually vacuolated. As a result of the swelling the lumen of the tubules has either been very greatly encroached upon or the lumen has become obliterated by an apposition of the opposing faces of the tubular epithelium. The epithelial changes are most pronounced in the convoluted tubules. (Figs. III and IV.)

In the animals grouped as practically anuric, the renal pathology is so nearly similar to the pathology of the kidney in the anuric group that the two allow no histological differentiation.

In the animals grouped as diuretic, the vascular pathology is similar histologically to the vascular pathology which has been described for those animals in the anuric group and also for those animals which were killed prior to the use of the anesthetic. The epithelial pathology, however, differes very much from the epithelial pathology of the anuric group but resembles in its appearance the epithelial reaction seen in those diuretic animals obtained before the use of an anesthetic. (Figs. V and VI.)

SUMMARY

1. Early in a uranium nephritis, usually within the first twenty-four hours, the animals develop a glycosuria and become markedly polyuric.

2. Following an anesthetic, morphine-ether, or Gréhant's, these animals either become completely anuric or the output of urine is greatly reduced.

3. Such animals under the effect of caffeine, theobromine, digitalin and 0.9 per cent salt solution, show a normal response

in the general blood pressure rise and in the vascular response of the kidney.

4. In certain of these animals the flow of urine is increased by these diuretics while in other animals the urine flow is uninfluenced.

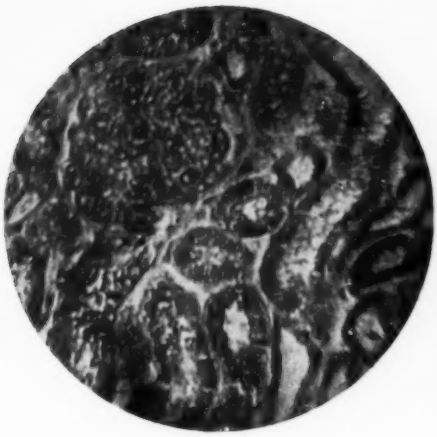
5. Histologically the vascular pathology of the kidney is similar in those animals which show a diuretic effect and in those animals which remain anuric.

6. Those animals which remain anuric show a physiological vascular response on the part of the kidney vessels similar to the response which is obtained in the diuretic animals. The physiological and the pathological reaction of the kidney vessels in the anuric and in the diuretic animals are, therefore, similar.

7. The two groups of animals differ, however, in the degree of involvement of the epithelial element of the kidney. The anuric animals show an epithelial involvement which is severe and which results anatomically in an encroachment upon, or occlusion of, the lumen of the tubules, while in the diuretic animals the epithelial changes are less marked and are insufficient to produce a mechanical obstruction of the tubular lumen.

8. The pathology of the kidney of those animals with an early uranium nephritis which were examined prior to the use of an anesthetic showed a vascular pathology which in general was similar to the vascular pathology of the anuric, practically anuric and diuretic animals. The tubular epithelium of these animals which were polyuric, showed but slight changes, and in their epithelial reaction the kidneys of these animals were more nearly comparable to the kidneys of the diuretic animals than they were to the kidneys of the anuric animals.

The physiological and anatomical observations which have been made in this investigation indicate that in a uranium nephritis the epithelial changes are more responsible for a reduction in the output of urine or an anuria than are the vascular changes. The way in which these changes influence the output of urine will furnish the basis for a subsequent investigation.



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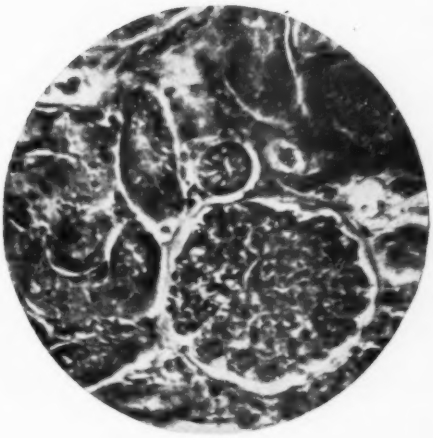

IV.

V.

VI.

Renal Pathology.

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Figs. I and II

The figures represent the kidneys of a nephritic, glycosuric and polyuric animal before the use of an anesthetic. The glomerular vessels fill and distend the surrounding capsule and show the presence of vacuoles in the capillary walls. The tubular epithelium shows occasion vacuolation, is but slightly swollen and has not encroached upon or occluded the lumen of the tubules. The tubules contain granular detritus. B. and L. obj. 3, oc. 1.

Figs. III and IV

The figures represent the kidneys of two animals which were excessively polyuric before the administration of an anesthetic. Following the anesthetic the animals became anuric. The anuria remained uninfluenced by the diuretics. The vascular pathology is histologically similar to the pathology described in the polyuric animals illustrated by Figs. I and II. The epithelial pathology, however, is strikingly different. The epithelium shows an acute swelling resulting in a nearly complete occlusion of the lumen of the tubules. The acute nature of the swelling of the epithelium is well shown in Fig. III. The anuria was uninfluenced by the diuretics. B. and L. obj. 3, oc. 1.

Figs. V and VI

The figures represent the kidneys of two animals which were responsive to the diuretics. The vascular pathology is similar to that described in the anuric animals. The epithelium shows but slight swelling and no material encroachment upon the lumen of the tubules. B. and L. obj. 3, oc. 1.

Chapel Hill, N. C.

NOTES ON THE BIRDS OF CHAPEL HILL, N. C., WITH PARTICULAR REFERENCE TO THEIR MIGRATIONS.

By Alexander L. Feild.

The material from which these notes are derived was gathered during my four undergraduate years at the University of North Carolina at Chapel Hill,—Sept. 1907 to June 1911. Since the migrating birds occur in the spring and autumn months, I was able to obtain tolerably complete records for the entire time. I made no observations during the three vacation months of June, July and August. A considerable amount of my spare time, however, during the school year was devoted to a study of the birds found in this region. The total number of species positively identified was one hundred and seven. Of this number twenty-nine are known to remain here all through the year and are therefore called permanent residents. Eleven are transient visitors,—birds which during the spring and fall migrations remain here for only a few days or weeks. Twenty are winter residents, which are birds that breed further northward but spend the winter in this locality. Thirty-three occur only in the summer, coming here to breed after their winter residence in the southern United States or the tropics. The remaining fourteen species are of doubtful classification.

I have added five new species to the hitherto catalogued species of Chapel Hill. They are the Red-tailed Hawk (*Buteo borealis borealis*), Red-cockaded Woodpecker (*Dryobates borealis*), Pine Siskin (*Spinus pinus*), Cape May Warbler (*Dendroica tigrina*), Kentucky Warbler (*Oporornis formosus*).

In 1899 Mr. T. G. Pearson published in this Journal (Vol. XVI, Part I) a "Preliminary Catalogue of the Birds of Chapel Hill, N. C., with Brief Notes on Some of the Species." One hundred and thirty-four species are included in this catalogue, one hundred and nineteen of which actually came under his notice. About all of the remaining seventeen species had been recorded previously by Prof. G. F. Atkinson. The latter

published in 1887 in the Raleigh *News and Observer* a "Preliminary List of Birds Collected in the Vicinity of Chapel Hill." Ninety-two species were listed. In an article entitled "A Preliminary Catalogue of the Birds of North Carolina," published in this Journal (Part 2 for 1887), Prof. Atkinson states that he identified about one hundred and twenty species at Chapel Hill, but does not enumerate them. No attempt was made by either of these observers to give any systematic record of bird migration at Chapel Hill.

Following my notes on the one hundred and seven species I met with, I have given a supplementary list of the thirty-three other species that have been previously listed for Chapel Hill, making a total of one hundred and forty. For further information concerning this last list, the reader is referred to Mr. Pearson's article, above mentioned.

The nomenclature used is that of the third edition of the A. O. U. Check List of North American Birds.

1. Green Heron (*Butorides virescens virescens*).

This heron is a summer resident. I did not find it as common as might be expected for this locality. In 1909 the first bird was seen on April 18.

2. Spotted Sandpiper (*Actitis macularia*).

I obtained only one record for this species. This was on April 18, 1909. It is not known to breed here.

3. Killdeer (*Oxyechus vociferus*).

I have seen this bird in December, February, March and April, the latest record being April 13, on which date one individual was seen. They are most abundant in March. No breeding record has been yet secured, although it is probable that they do breed. It is a tolerably common resident in the middle section of the state.

4. Bob-white (*Colinus virginianus virginianus.*)

A common resident throughout the year. I have observed numerous coveys on the campus.

5. Mourning Dove (*Zenaidura macroura carolinensis*).

This bird is common at all times of the year. It is classed

as a game-bird. In 1909 I first heard the Dove's call on February 14; in 1908, on March 8.

6. Turkey Vulture (*Cathartes aura septentrionalis*).

This vulture, commonly called "Turkey Buzzard," may be seen every month of the year. It breeds in this region.

7. Black Vulture (*Catharista urubu*).

A flock of these vultures was seen on January 22, 1909. It may breed in this region, as it has been recorded as a resident in the eastern and middle portions of the state.

8. Sharp-shinned Hawk (*Accipiter velox*).

The only time recorded was on February 9, 1909. There seems to be a scarcity of hawks of all kinds in the region around Chapel Hill.

9. Red-tailed Hawk (*Buteo borealis borealis*).

This hawk was noted only once, April 24, 1909. It has not been recorded by any earlier observer at Chapel Hill.

10. Red-shouldered Hawk (*Buteo lineatus lineatus*).

This is apparently the commonest member of the family in this locality. I have only observed it in December, February, March and April, however.

11. Sparrow Hawk (*Falco sparverius sparverius*).

Next to the Red-shouldered Hawk, the Sparrow Hawk is most often seen. One pair evidently nested in the oaks back of the South Building.

12. Barred Owl (*Strix varia varia*).

In the winter and spring months these birds were heard calling night after night in the forest south of the campus and in Battle's Park. Sometimes several would be heard at once.

13. Screech Owl (*Otus asio asio*).

This little owl is often heard on the campus. I never actually saw but one individual here.

14. Yellow-billed Cuckoo (*Coccyzus americanus americanus*).

This "Rain-Crow" was first seen on May 17 in 1908, and on April 28 in 1911. It is a not uncommon summer resident.

15. Belted Kingfisher (*Ceryle alcyon*).

I have observed this species only in March, April and May, the earliest record being March 25, and the latest May 2. It probably breeds. No record of it has yet been obtained.

16. Hairy Woodpecker (*Dryobates villosus audubonì*).

This bird is not at all uncommon around Chapel Hill. I have seen it in November, December, January, April, and May. The latest spring record was May 27. It breeds here without doubt.

17. Downy Woodpecker (*Dryobates pubescens*).

This is the smallest and most abundant woodpecker at Chapel Hill. It was seen in all months of the year. I met with it most frequently in February. In the middle of this month it starts its loud drumming, which is the mating-call

18. Red-cockaded Woodpecker (*Dryobates borealis*).

The woodpecker has not been recorded for Chapel Hill by earlier observers. I found it a not uncommon bird in Battle's Park and other neighboring woods. This species was seen by me five times in the months of March and April, 1909, the latest being on April 17. The Red-cocaded Woodpecker was usually observed in numbers ranging from two to six.

19. Yellow-bellied Sapsucker (*Sphyrapicus varius varius*).

This common migrant woodpecker occurs here. The average date of its arrival was October 16. The earliest were on Octo- 11 in 1907 and 1911. The latest time at which it was seen in the spring was on April 26 in 1911. It was noted in all the intervening months except November, but was most abundant from January 15 to February 15.

20. Pileated Woodpecker (*Phloeotomus pileatus pileatus*).

This large bird was seen on four occasions, the dates being November 28, 1907, January 9, January 22, February 20, 1909. On three of these occasions it was found in the forest several miles south-east of the campus. Only one individual was seen at any one time.

21. Red-headed Woodpecker (*Melanerpes erythrocephalus*).

This handsome bird is a very conspicuous inhabitant of the campus. It is not so abundant in the surrounding region. It seemed most numerous in May. I have no records for December, nor for the first three weeks in January. In 1909 the loud drumming mating-call was first heard on February 5.

22. Red-bellied Woodpecker (*Centurus carolinus*).

One of the anomalies of Chapel Hill ornithology is the abundance of this woodpecker, which is rare in very similar localities. I observed one pair nesting in a hole in an elm in the back-yard of the old Archer place. The time was April. I have also seen this bird during the fall and winter months, except February.

23. Flicker (*Colaptes auratus auratus*).

Next to the Downy the commonest woodpecker. I found it most conspicuous in March. It is a resident species.

24. Whippoorwill (*Antrostomus vociferous vociferous*).

The average date of arrival of this migrant was April 5. The earliest arrival was noted on March 31, 1910. These birds during the spring migrations may be heard calling in large numbers in Battle's Park and the woods south of the campus. Those individuals that remain to breed continue their calling through the first week in May.

25. Nighthawk (*Chordeiles virginianus virginianus*).

This bird breeds at Chapel Hill. I saw one bird perform for several successive evenings the sky-coasting performance, for which the species is famous, over the cemetery and adjoining woods. This was about May 1, 1911. The earliest record I obtained was April 11, in 1908. In 1911 I saw it as late as October 7.

26. Chimney Swift (*Chaetura pelagica*).

My records for the arrival of this well-known summer visitor are as follows: March 31, 1908, April 4, 1909, April 4, 1910, April 5, 1911. In 1908 and 1909 it was last seen on October 10; in 1907, on October 9. In the fall, just before they leave,

these swifts gather in great numbers in the chimneys of the South Building.

27. Ruby-throated Hummingbird (*Archilochus colubris*).

Arrived on April 16 in 1908, and on April 15 in 1909. A common summer resident.

28. Kingbird (*Tyrannus tyrannus*).

I found the Kingbird not very common at Chapel Hill. The earliest spring arrival was on April 26, 1908. In 1907 it was seen as late in the fall as September 3. This flycatcher is not as abundant as in many similar sections of the state.

29. Crested Flycatcher (*Myiarchus crinitus*).

Earliest spring arrival, April 16, 1908 and 1910; average arrival, April 18. Last seen in the fall of 1907 on September 17. This is a very common bird at Chapel Hill, breeding on the campus.

30. Phoebe (*Sayornis phoebe*).

A nest containing three eggs and one young was found by me on April 24, 1909, under the eaves of a mill near Chapel Hill. I have observed the Phoebe during all the nine months of the school year. It was most abundant in February.

31. Wood Pewee (*Myiochanes virens*).

A very common summer resident. Average time of arrival was April 27; earliest arrival was on April 24, 1907. The Wood Pewee was last seen in 1907 on October 14.

32. Acadian Flycatcher (*Empidonax virescens*).

A rather common summer resident. It usually appeared about May 4. Earliest arrival on May 1, 1910.

33. Blue Jay (*Cyanocitta cristata cristata*).

An abundant resident of the campus. It is not so numerous, however, in the surrounding region.

34. Crow (*Corvus brachyrhynchos brachyrhynchos*).

A common permanent resident.

35. Bobolink (*Dolichonyx oryzivorus*).

Small flocks of these migrants were seen April 3-7, 1908,

April 7, 1909, April 5, 1911, on the campus. The males were in song on each occasion.

36. Red-winged Blackbird (*Agelaius phoeniceus phoeniceus*).

This bird is perhaps a rare summer resident. I have it recorded only during November, however. The scarcity of this and other species of similar breeding habits may be due to the absence of much swamp-land or many ponds near Chapel Hill.

37. Meadowlark (*Sturnella magna magna*).

It may be that these birds breed occasionally here. No record, however, has been obtained. I have observed them from October 22 to April 22. The Meadowlark begins to sing about January 8 and continues until March 30. They are common birds on the campus in the winter and spring months.

38. Orchard Oriole (*Icterus spurius*).

A summer resident on the campus. Is a tolerably common species. Average appearance in spring, April 28; earliest, April 22, 1909.

39. Baltimore Oriole (*Icterus galbula*).

One individual was observed on April 27, 1908, in the arboretum. There is only one other record for this species at Chapel Hill, this being May 2, 1901.

40. Purple Grackle (*Quiscalus quiscula quiscula*).

Only seen on March 5, 1908, and February 12, 1911.

41. Purple Finch (*Carpodacus purpureus purpureus*).

This winter visitor is abundant at Chapel Hill during March and part of April. The latest records I obtained were on April 23 in 1909 and 1911. I did not see it at all in the fall; nor earlier in the winter than February 2. The Purple Finch sings continually from about Februtry 14 until it leaves in the spring.

42. English Sparrow (*Passer domesticus*).

Abundant in town and spreading into the country.

43. Goldfinch (*Astragalinus tristis tristis*).

A common permanent resident, abundant during March and April. Begins to sing about March 19. Found associated largely with the Purple Finch.

44. Pine Siskin (*Spinus pinus*).

This uncommon transient visitor was noted in abundance on the campus from April 23 to May 6, 1911. These are the first recorded at Chapel Hill.

45. Vesper Sparrow (*Pooecetes gramineus gramineus*).

First seen in 1908, on October 30; was seen in December; and on April 3, 1909. A rather uncommon winter visitor.

46. Savannah Sparrow (*Passerculus sandwichensis savanna*).

I only saw this bird in the spring of 1909. It occurs probably as a regular winter bird. I found it common in the arboretum from April 2 to April 23. One individual was heard to sing on April 18.

47. Grasshopper Sparraw (*Ammodramus savannarum australis*).

Observed only on May 30, 1908, and April 10, 1911. It is not known to breed here, but probably does.

48. White-throated Sparrow (*Zonotrichia albicollis*).

An abundant winter visitor. Length of stay: October 14, 1907, to April 11, 1908; October 16, 1908, to May 7, 1909; — — — to May 5, 1910; October 13, 1910, to May 7, 1911. Sings during its entire stay, but most frequently in April.

49. Chipping Sparrow (*Spizella passerina passerina*).

Abundant as a summer resident. Spring arrivals are as follows: March 6, 1908, February 28, 1909, March 9, 1910. It usually leaves about November 10. On December 10, 1907, however, quite a number were seen on the campus.

50. Field Sparrow (*Spizella pusilla pusilla*).

This common permanent resident begins to sing regularly about February 14. One individual was heard as early, however, as January 22.

51. Slate-colored Junco (*Junco hyemalis hyemalis*).

The "Snow-bird" is a very common winter visitor. The average date of arrival was November 10; the earliest, October 25, 1908. In the spring it was seen until April 15 in 1909.

The Junco begins to sing about February 17 and continues until its departure in April.

52. Bachmans Sparrow (*Peucaea aestivalis bachmani*).

A not uncommon bird at Chapel Hill. It arrived in 1908 on April 26, and in 1909 on April 17. I am of the opinion that one pair of these birds usually breeds in the neighborhood of the cemetery.

54. Song Sparrow (*Melospiza melodia melodia*).

My records of the length of stay of this common winter visitor are: October 22, 1907, to March 29, 1908; October 20, 1908, to April 8, 1909; October 21, 1910, to ——. Its song is heard throughout its residence here, but it is most frequently heard during March.

55. Swamp Sparrow (*Melospiza georgiana*).

Observed on only one occasion in the winter (date not known). By no means a common bird in this locality.

56. Fox Sparrow (*Passerella iliaca iliaca*).

This winter visitor arrived in 1907 on November 28. I found it much commoner in the first three months of the year than in November or December. It was last seen in 1909, on March 18. Its song was heard in January, February, and March.

57. Towhee (*Poplio erythrophthalmus erythrophthalmus*).

This bird finds a very congenial winter home in the valleys of Chapel Hill. I found the usual date of arrival to be October 16 (earliest, October 11, 1907). This bird lingers in the spring as late as May 6, which is the average of three years' observations. The last bird seen in 1909 was on May 9. The Towhee begins to sing in the middle of February and continues until about April 6.

58. Cardinal (*Cardinalis cardinalis cardinalis*).

A common resident all the year. Begins to sing in January, but is not in full voice until February 15.

59. Rose-breasted Grosbeak (*Zamelodia ludoviciana*).

One male observed on April 28, 1908, in the village. A rare transient visitor.

60. Blue Grosbeak (*Guiraca caerulea caerulea*).

A not uncommon bird during the spring migration. Arrived on the following days: May 9, 1908, May 9, 1909, May 1, 1910, May 24, 1911. It is without doubt a summer resident here.

61. Indigo Bunting (*Passerina cyanea*).

A very common summer resident, the bird's average arrival for three years being April 24 (earliest record, April 23, 1909, 1911). The Indigo is a persistent singer from the time of its arrival until late summer.

62. Scarlet Tanager (*Piranga erythromelas*).

In 1910 this was a rather common bird on the campus from May 10 to 16. It was not seen at any other time. A rather uncommon transient visitor at Chapel Hill.

63. Summer Tanager (*Piranga rubra rubra*).

This Tanager is the common form at Chapel Hill. It is a resident in the summer. The extreme length of stay was from April 15 (1909) to September 26 (1907). I found it to arrive usually about April 20.

64. Purple Martin (*Progne subis subis*).

In 1908 this swallow, which is rather uncommon at Chapel Hill, arrived on April 22. In 1907 one individual was seen on September 7. I do not know of any that nest here.

65. Barn Swallow (*Hirundo eythrogastra*).

Observed only in the spring of 1908, May 6 to 8, and in the fall of 1909, September 17. On both occasions the birds were migrating in flocks of eight or ten individuals.

66. Rough-winged Swallow (*Stelgidopteryx serripennis*).

The earliest appearance of this bird was on April 10, 1910. It is perhaps a rather uncommon summer resident. In the migration season, however, it is more numerous, being seen regularly every year.

67. Cedar Waxwing (*Bombycilla cedrorum*).

I have seen the Cedar-bird from October 29 to November 8, and from January 4 to May 30. It probably occurs also in December. It is not certain whether it breeds in this locality or not. There are no records of its nesting here. It is very common in the late winter and spring.

68. Loggerhead Shrike (*Lanius ludovicianus ludovicianus*).

My only record for this bird was on October 15, 1907, when one individual was seen in the village. It is a rare winter visitor.

69. Red-eyed Vireo (*Vireosylva olivacea*).

This is the commonest Vireo at Chapel Hill, arriving from the south about April 22 (earliest record, April 18, 1908). It breeds abundantly.

70. Yellow-throated Vireo (*Lanivireo flavifrons*).

A summer resident, almost as abundant as the Red-eyed Vireo, and fully as persistent a songster. It arrives about April 15. (Earliest record, April 8.) In 1907 it was seen in autumn as late as September 21.

71. Blue-headed Vireo (*Lanivireo solitarius solitarius*).

Two birds were observed in the fall of 1907 in the village (date not exactly known).

72. White-eyed Vireo (*Vireo griseus griseus*).

Not as common as would be expected for this locality. A summer resident. Arrived in 1908 on March 29, the average appearance being on April 6.

73. Black and White Warbler (*Mniotilta varia*).

This warbler usually arrived on the first of April (earliest record, March 28, 1909). It breeds here and is tolerably common.

74. Parula Warbler (*Compsothlypis americana americana*).

Usually arrives about April 8. In 1910 the Parula Warbler appeared on April 3, which was my earliest observation. It is very common during the migration season and until May 15. It probably breeds at Chapel Hill. I have an entry for this

species on September 2, 1907, which was as late as I found it in the fall.

75. Cape May Warbler (*Dendroica tigrina*).

In the spring of 1909 this rare bird was tolerably common in the oaks on the campus from April 26 to May 3. These are the first recorded at Chapel Hill, and must be regarded as very rare transient visitors.

76. Yellow Warbler (*Dendroica aestiva aestiva*).

Spring arrivals were: April 20, 1908, April 19, 1909, April 16, 1910, April 18, 1911. Last bird seen in 1907 on September 20. A tolerably common breeding bird.

77. Black-throated Blue Warbler (*Dendroica caerulescens caerulescens*).

Observed only once, on April 25, 1909, in the arboretum.

78. Myrtle Warbler (*Dendroica coronata*).

This warbler is a common winter visitor, reaching Chapel Hill as follows: October 14, 1907, October 25, 1908, October 22, 1909, October 21, 1910. It becomes extremely abundant in March, is less abundant in April, and leaves early in May. (Latest observed, May 15, 1910.)

79. Black-poll Warbler (*Dendroica striata*).

I found this warbler a regular transient visitor, which, during its stay, was almost abundant. It was recorded each year, the earliest arrival being April 29, 1911, the latest May 7, 1908. In 1910 it remained until May 22. Its song was heard during its short residence very often. It was not seen in the fall.

80. Yellow-throated Warbler (*Dendroica dominica dominica*).

An early spring migrant, whose coming was noted as follows: April 7, 1908, March 28, 1909, March 29, 1910, April 7, 1911. In 1907 it was seen until September 14. It breeds and is tolerably common,—very common during the migrations.

81. Pine Warbler (*Dendroica vigorsi*).

A resident all the year and is very common at Chapel Hill. It begins to sing regularly about February 15, although on

warm days in December and January it occasionally bursts into song. It continues to sing until October.

82. Prairie Warbler (*Dendroica discolor*).

A common summer resident in the thickety hill-sides around Chapel Hill. My records for spring arrivals for four years all lie between April 14 and April 18. In 1907 it was noted on September 15.

83. Oven-bird (*Seiurus aurocapillus*).

This bird appeared in the spring during my four years stay from April 10 to April 21. It is without doubt a summer resident; during the migration it is common, becoming only tolerably common later in the year.

84. Louisiana Water-thrush (*Seiurus motacilla*).

This warbler is a resident at Chapel Hill. It appeared in the spring as follows: March 29, 1908, April 15, 1909, March 24, 1910. In 1907 it was seen on September 6.

85. Kentucky Warbler (*Oporornis formosus*).

This bird, which is a rather uncommon summer resident, was first observed in 1909 on May 18. It was noted quite frequently in the woods south of the campus. It has not been hitherto listed as occurring at Chapel Hill.

86. Maryland Yellowthroat (*Geothlypis trichas trichas*).

The first migrants were noted as follows: April 4, 1908, March 29, 1909, April 2, 1910, April 23, 1911. In 1907 it was last seen on October 14, in 1908 on October 19. I found it not very common at Chapel Hill. It breeds here.

87. Yellow-breasted Chat (*Icteria virens virens*).

A very common species, resident in summer. Its appearance was as follows: April 21, 1908, May 9, 1909, May 1, 1910. In 1911 I saw none of these birds, although I looked for them carefully until my departure on May 30.

88. Hooded Warbler (*Wilsonia citrina*).

Observed only on April 24, 1908, in Battle's Park.

89. Redstart (*Setophaga ruticilla*).

Recorded in the spring on April 24, 1908, May 4, 1910: in

the fall, on September 14, 1907, and September 18, 1908. A rather uncommon transient visitor.

90. Pipit (*Anthus rubescens*).

Regularly observed in the winter, being very common at times. Arrived on November 2 in 1908, on October 17 in 1910, and October 22 in 1911. I saw them as late as March 7 (1910). They were often seen near the railroad station and in the athletic field.

91. Mockingbird (*Mimus polyglottos polyglottos*).

This common, permanent resident was heard to sing in every month except September. Its song, however, was heard most in March and April. Often in the spring this peerless songster would sing for hours at night on the campus.

92. Catbird (*Dumetella carolinensis*).

A common summer form, making his appearance in the spring on April 16 to 20. Last seen in 1907 on October 14.

93. Brown Thrasher (*Toxostoma rufum*).

I did not see these birds earlier in the winter than February 14, although it is probable that they stay here in small numbers all through the year. They begin to sing immediately on appearing,—the song being usually mistaken for that of the Mockingbird. They become abundant during March, but fall off in numbers after the wave of migrating birds has passed over.

94. Carolina Wren (*Thryothorus ludovicianus ludovicianus*).

A very common resident all the year. Sings more or less during the whole twelve months.

95. Winter Wren (*Nannus hyemalis hyemalis*).

A rather common winter bird. Arrived in 1907 on October 14. Remained in 1909 until April 15. Have not heard it sing at Chapel Hill.

96. Brown Creeper (*Certhia familiaris americana*).

This bird was seen only in December, February and March. Only in March does it become at all common. In 1909 it was seen until March 23.

97. White-breasted Nuthatch (*Sitta carolinensis carolinensis*).
A very common permanent resident. The prolonged nasal song of this Nuthatch begins to be heard frequently about the middle of January. The song period reaches its maximum in March or April.

98. Brown-headed Nuthatch (*Sitta pusilla.*)
A not uncommon permanent resident. I have seen immature birds of the year.

99. Tufted Titmouse (*Baeolophus bicolor*).
This is a very common resident species.

100. Carolina Chickadee (*Penthestes carolinensis carolinensis*).
Like the Titmouse, a very common permanent resident.

101. Golden-crowned Kinglet (*Regulus satrapa satrapa*).
Arrived in the fall on the following dates: October 15, 1907, October 16, 1908, October 21, 1909, October 12, 1911. This species remains in the pine forests around the village until near the middle of April (April 11, 1908, April 14, 1910).

102. Ruby-crowned Kinglet (*Regulus calendula calendula*).
More of a transient visitor than a winter resident, being rather common in October and March. In 1907 it arrived on October 24, in 1908 on October 25. It arrived for its spring stay on March 18 and was seen until April 21 in 1909. Again, in 1911, this Kinglet was noted until April 23. Its song is often heard during the spring.

103. Blue-gray Gnatcatcher (*Polioptila caerulea caerulea*).
This tiny bird comes usually from the south in the last part of March. The average date of its appearance was March 30 (earliest, March 22, 1908). It is a common summer bird. In 1907 it was seen as late as September 23.

104. Wood Thrush (*Hylocichla mustelina*).
This handsome bird and its sweet song are characteristic of the campus in spring and summer. The extreme length of its stay was from April 8 (1909) to September 23 (1907). The average time of its appearance in spring was April 13.

105. Hermit Thrush (*Hylocichla guttata pallasi*).

This Thrush takes the place of the Wood Thrush when winter approaches. It came on October 15 in 1907, and on November 2 in 1908. In 1909 the Hermit stayed until April 8. It is a common winter bird but does not sing while here.

106. Robin (*Planesticus migratorius*).

A conspicuous resident on the campus, where it breeds. A few remain at Chapel Hill all the year. In February and March , however, the migrating birds reach here and their numbers increase very much. The Robin begins to sing toward the end of January.

107. Bluebird (*Sialis sialis sialis*).

I found this bird common at Chapel Hill at all seasons of the year. In February and March it is abundant on the campus.

The thirty-three species which follow have been previously recorded at Chapel Hill.

1. Holboells Grebe (*Colymbus holboelli*). One specimen taken by Prof. Atkinson in 1877.
2. Pied-billed Grebe (*Podilymbus podiceps*). Recorded by Mr. Pearson.
3. Loon (*Gavia immer*). There are two specimens in the University collection with no date attached.
4. Wood Duck (*Aix sponsa*). Recorded by Mr. Pearson.
5. Bittern (*Botaurus lentiginosus*). Recorded by Prof. Atkinson.
6. Great Blue Heron (*Ardea herodias herodias*). Catalogued by Mr. Pearson.
7. Egret (*Herodias egretta*). One specimen shot by Mr. Dedrick in 1894.
8. Sora (*Porzana carolina*). One taken in November, 1887, now in the University collection.
9. Coot (*Fulica americana*). One recorded by Prof. Atkinson on April 8, 1887.
10. Woodcock (*Philohela minor*). Catalogued by Mr. Pearson.

11. Wilsons Snipe (*Gallinago delicata*). Catalogued by Mr. Pearson.
12. Solitary Sandpiper (*Helodramas solitarius solitarius*). Listed by Prof. Atkinson.
13. Wild Turkey (*Meleagris gallopavo silvestris*). Recorded by Mr. Pearson.
14. Marsh Hawk (*Circus hudsonius*). Catalogued by Mr. Pearson, one specimen being secured on April 5, 1899.
15. Coopers Hawk (*Accipiter cooperi*). Catalogued by Mr. Pearson.
16. Broad-winged Hawk (*Buteo platypterus*). One specimen recorded by Mr. Pearson.
17. Bald Eagle (*Haliaeetus leucocephalus leucocephalus*). One observed by Mr. Pearson.
18. Great Horned Owl (*Bubo virginianus virginianus*). Catalogued by Mr. Pearson.
19. Chuck-wills-widow (*Antrostomus carolinensis*). One individual heard by Mr. Pearson on May 20, 1899.
20. Horned Lark (*Otocoris alpestris alpestris*). Recorded by Mr. Pearson on November 23, 1898.
21. Rusty Blackbird (*Euphagus carolinus*). Catalogued by Mr. Pearson. Two killed by Mr. Ivy Lewis on February 3, 1899.
22. Tree Sparrow (*Spizella monticola monticola*). Listed by Prof. Atkinson.
23. Tree Swallow (*Iridoprocne bicolor*). Catalogued by Mr. Pearson.
24. Worm-eating Warbler (*Helmitheros vermivorus*). Catalogued by Prof. Atkinson.
25. Magnolia Warbler (*Dendroica magnolia*). Two specimens taken by Mr. Pearson in September, 1897.
26. Chestnut-sided Warbler (*Dendroica pensylvanica*). One bird taken by Mr. Pearson on September 21, 1897.
27. Bay-breasted Warbler (*Dendroica castanea*). One taken by Mr. Pearson on October 2, another on October 8, 1897.

28. Blackburnian Warbler (*Dendroica fusca*). One bird killed by Mr. Pearson on October 16, 1897.
29. Black-throated Green Warbler (*Dendroica virens*). Catalogued by Mr. Pearson.
30. Water thrush (*Seiurus noveboracensis noveboracensis*). Seen by Mr. Pearson.
31. House Wren (*Troglodytes aedon aedon*). Listed by Prof. Atkinson.
32. Veery (*Hylocichla fuscescens fuscescens*). Listed by Prof. Atkinson.
33. Olive-backed Thrush (*Hylocichla ustulata swainsoni*). One specimen secured by Mr. Pearson on September 26, another on October 9, 1897.

There are a number of species which probably occur at Chapel Hill but have not been observed up to this time. Some of these are Little Blue Heron (*Florida caerulea*), King Rail (*Rallus elegans*), Black-billed Cuckoo (*Coccyzus erythrophthalmus*), Cowbird (*Molothrus ater ater*), Bank Swallow (*Riparia riparia*), and Red-breasted Nuthatch (*Sitta canadensis*).

Raleigh, N. C.

THE SEEDLINGS OF THE LIVE OAK AND WHITE OAK.

By W. C. Coker.

In the Plant World for May, 1911, Mr. Isaac Louis has an interesting article on the germination of the acorn of *Quercus virginiana*. So far as I know his figures of the live oak seedling are the first published, but he overlooks the previous publication of most of the facts by others.

The appearance of a tuberous swelling on the root of the seedling of this species was first discovered by Mr. William St. J. Mazyck, of Georgetown, South Carolina, who, by letters and specimens, called the attention of several botanists to the fact. Among those he communicated with were Dr. George Engelmann, of St. Louis, and Mr. Thomas Meehan, of Germantown, Pennsylvania. In the Transactions of the Academy of Science of St. Louis, Vol. IV, 1880, Dr. Engelmann has an article on "The Acorns and their Germination," which opens as follows:

"The structure of the acorns and the germination of the oaks seem to be so well known, that I did not pay much further attention to it until my interest was excited by the information that the germinating live-oak developed little tubers, well known to the negro children, and greedily eaten by them. The notes and specimens obtained from my South Carolina correspondents, Messrs. H. W. Ravenel, W. St. J. Mazyck (who was the first to notice this), and Dr. J. H. Mellichamp, enabled me to examine the germinating live-oak and to compare it with other oaks in this condition."

After describing the usual process of sprouting in oaks he says:

"The process in *Q. virens*[1] is essentially the same; it differs somewhat in that the connate stalk of the cotyledons remains more slender, but elongates more, mostly to the extent of one inch or even more; the cuticle and the upper part of the root

[1] *Quercus virens Ait* is another name for the live oak, *Quercus virginiana Mill.*

swells up at once, while the developing plumule forces its way up through a slit in the base of the stalk. It seems that the danger of losing connection with the storehouse of the cotyledonous mass through the long and slender passage of the stalk, necessitates the transfer of the food-matter to a nearer and safer place of deposit. But why, it may be asked, is the connection so much longer and more slender than in the other oaks? At all events it suffices, so long as it is fresh and unimpaired, to carry over in a very short time the starchy and sweet contents from the cotyledons to the tuber; and before the ascending axis is an inch high and bears as yet only a few minute bracts, the tuber is already forming and it soon reaches the size of the cotyledons themselves; it is, however, longer and more slender, of a fusiform shape, about three or four lines thick and one or two inches long, attenuated below into the long tap-root."

"The whole process is similar to the germination of the cucurbitaceous Magarrhiza of California, so beautifully illustrated by Gray in his structural Botany; with this difference, that the cotyledons in that plant are raised above the ground,[2] while in ours they remain hypogaeous, and that the stalk is even longer, and is, together with the cotyledons, readily separable into its two component parts. In both plants a tuber forms at once by the transfer of the food-matter from the cotyledons to the radical; in the herbaceous Megarrhiza the tuber becomes a permanent organ of immense size, while in the arboreous live-oak it is finally merged into the root."

It may be of interest, also, to give two of Dr. Engelmann's letters to Mr. Mazyck (not before published), in which this subject is referred to. On March 10th, 1880, he writes:

"WM. ST. J. MAZYCK, ESQ.,

Dear Sir:—You will find from a little paper which I published in the St. Louis Academy Transactions, and which I will send in a few days, that I studied not only the germination but also the structure of the acorn itself and find in it an interesting character.

[2] "But only exceptionally" is the foot note at this point by the editors of Dr. Engelmann's collected works.

I forget how far I entered into this matter in my last, of Feb. 21st, but if I should repeat myself here you will forgive me.

You know how a bean and a pea germinate: both with thick fleshy cotyledons which do not expand into leaves, as many plants do. The difference between them is that the cotyledons of the pea remain under ground, while the bean's are elevated on the stem above it.

Well, the acorns behave like the pea, but the cotyledons remain enclosed in the shell while their stems or stalks, or petioles come out and enclose between them the stem which grows up. If you pick up any seedling oak, you will find it so, and removing the shell, you can separate the cotyledons from one another and examine the whole arrangement.

In most white-oaks the stems are longer, in the black-oaks shorter, and that is already seen in the acorn itself. In the live-oak it is longest already within the acorn, and in all of them it lengthens in germination more or less.

The question with me now is, how soon does the tuber in the live-oak swell and how long does it last.

I suppose that it begins to swell immediately when formed, attaining its full size, perhaps, in the fall, or it may grow for several years. I have a young live-oak, apparently three years old, with the biggest tuber I have ever seen.

And I suspect that the tuber is hardly absorbed but gradually merged into the root. . . . . "

On April 7th, 1880, he writes again:

"WM. ST. J. MAZYCK, ESQ.,

Dear Sir:—Enclosed please find the results of my studying of the germination of acorns and of their structure.

In regard to the germinating *Q. virens* we ought to know yet:

1st. How soon the tuber forms: from your many accounts I judge that it forms before any leaves are developed.

2nd. When the cotyledons are exhausted and what relation their increase bears to the increase of the tuber.

How long the tuber continues to grow larger, and at what age of the plant it becomes merged in the root or base of the trunk.

I have a specimen about four or five years old, in which the tuber is the largest of any I have ever seen, but, of course, hard and ligneous.

Seedlings of Live Oak.

By examining other acorns but those of the live-oak you will be able to find out what by my description is meant."

Mr. Thomas Meehan, a well known horticulturist of that time, also gave an account of the live-oak seedling, before the Philadelphia Academy of Natural Science. In the Society's Transactions for the year 1880, pages 128 and 129, we find the following:

"Mr. Thomas Meehan referred to some interesting facts in the germination of *Quercus virens,* as brought to his attention by W. St. J. Mazyck, of Georgetown, S. C. It was generally known that in this species the cotyledons did not divide into two lobes as usual in acorns, but seemed to be one solid mass, without any trace of division. In germination, however, two petioles were developed as in other acorns, but instead of these being very short, indeed nearly sessile, as in the ordinary white-oak, they were produced apparently in the much advanced specimen sent by Mr. Mazyck to one and one-half inches in length before the plumule and hypocotyledenary portions of the embryo commenced their growth. In respect to the latter, a small ovate striate tuber, apparently, as one might judge from the shrivelled specimens on hand, nearly one-fourth the size of the acorn, was formed, and from the tuber the radicle proceeded, and, afterwards the plumule on its upward growth. . . . . .

"Mr. Edward Potts, at the request of Mr. Meehan, had made sections of both the acorns and the spindle-shaped radicle, with the results of finding the cell structure of the latter an almost exact counterpart of that of the nut: *i. e.,* sub-spherical cells of uniform size, gorged with starch grains. So similar were they that it would be nearly impossible for an observer to say which he was examining but for the cortical tissue surrounding the root. It seemed that the food supply of the young plant had been thus withdrawn from a portion exposed to hot sun and drying winds to be protected by the earth and in the direct line of growth. No line of specialized cells could be discovered in the sections of the nut, indicating the possibility of separation as in other species into two cotyledons; so that to all intents and purposes it might be called monocotyledonous."

In an unpublished letter, of February 6, 1880, to Mr. Mazyck, Mr. Meehan says:

"I am very much obliged by your letter and samples of live-oak. I knew before that this species is monocotyledonous, and that the development of the radicle and ultimately plumule, is as you describe. Other oaks have somewhat the same character, but not the same degree. But I did not know of the swelling of the radicle. I shall call the attention of the Academy of Science to this interesting fact at its next meeting. . . . "

In a later letter (February 29, 1880) we find the following:

" . . . The acorn matter was very interesting to the members. Some examinations of other species have since been made, and it is found that so far as the lengthening of the petioles of the cotyledon is concerned, many have it to a greater or less degree, and the discovery of yours will be of very great value in the determination of the species. Drawings will be made and published of many species, but I made a formal address before the Academy at its meeting on last Tuesday evening, so that the discovery may be placed on record to your credit. It may be some months before this is published officially by the Academy, but as soon as it is I will send you a copy.

One of the tubers was examined microscopically by Mr. Potts of the Microscopical Section, and found to contain starch granules of precisely the same character as those of the original cotyledon.

Thanking you for your interesting facts, I am,

Very truly yours,

THOMAS MEEHAN,
2nd Vice-President Academy of Natural Science of Philadelphia

In my article on Dr. Mellichamp (Journal of the Elisha Mitchell Scientific Society, May, 1911), I published, on page 50, a letter of Dr. Mellichamp's which is concerned in part with this matter. He says:

"If I could only have received these queries when I was last in Bluffton I could have answered them accurately, but now I cannot do so, and I do not wish to trust to my memory of some years back when I not only planted the live-oak acorns, but

examined the young roots after a year or two and even reported the results to my dear friend Engelmann, of St. Louis, who had been put on the track by Wm. St. J. Mazyck, who spent a pleasant morning with me at the mill, when I was last at Charleston. . . . "

As Mr. Lewis did not publish any late stages of the seedlings, it may be of interest to show the accompanying photograph (Plate II), of three seedlings about fifteen months old taken by me last fall. The plant in the center shows the interesting peculiarity of having a cluster of small tubers instead of a single large one.

In one of the above quotations from Dr. Engelmann he asks why the petiole of the cotyledons should be so much longer in the live-oak than in the other oaks. The answer is probably to be found, as suggested in the Proceedings of the Philadelphia Academy, and as expressed by Mr. Lewis, in the "advantages to the plant in establishing itself in the semi-arid situations in which it is often found." In the South-Eastern States at least the live-oak is partial to very sandy soils near the shore, and such soils are necessarily subject to rapid surface desiccation. Retention of the food stuff in the cotyledons for a long time would be dangerous, as the cotyledons might be prematurely dried and killed.

In regard to the association of fused cotyledons and the tuberous habit, there is a very interesting analogy, that does not seem to have been noticed before, between the live-oak and a number of other dicotyledons. In the development of her theory of the origin of monocotyledons, Miss Ethel Sargant has clearly brought out the existence of a close correlation between the geophilous[1] habit and a fusion of the cotyledons. In the Botanical Gazette, for May, 1904, Miss Sargant[2] has an article on "The Evolution of the Monocotyledons," in which she writes as follows in regard to dicots with fused cotyledons:

[1] The live oak does not, technically, come under Prof. Areschong's definition of a geophilous plant, as it does not periodically lose its above-ground parts; but it is, nevertheless, a geophilous plant in its youth.

[2] See, also, Miss Sargant's more recent article in *Annals of Botany*, Vol. XXII, p. 121, 1908, where the literature is given.

"They belong to eight genera which are systematically scattered, for they represent six families, *Ranunclaceae, Fumariacea, Umbelliferae, Primulacae, Lentibularieae* [sic], *Nyctagineae.* Clearly these species cannot have inherited the peculiar form of their seedling from a common ancestor. It must be due to similar external conditions affecting certain species of very different descent in the same way.

"One feature is common to all of the pseudo-monocotyledons in my list—they all possess some underground member which is thickened into a tuber. In *Ranunculus Ficaria* one of the earlier cauline roots became tuberous; in the other species the hypocotyl is more or less thickened.

"Moreover, the most complete list I can make of dicotyledons with their cotyledons partially united for some distance from the base upwards included twenty genera. It contains but one genus—*Rhizophora*—in which the hypocotyl is not very much shortened, if not actually thickened. In the great majority the hypocotyl becomes a conspicuous tuber. The seeds of the single exception germinate under peculiar conditions, which would account for most any amount of modification in the structure of the seedling. . . . . "

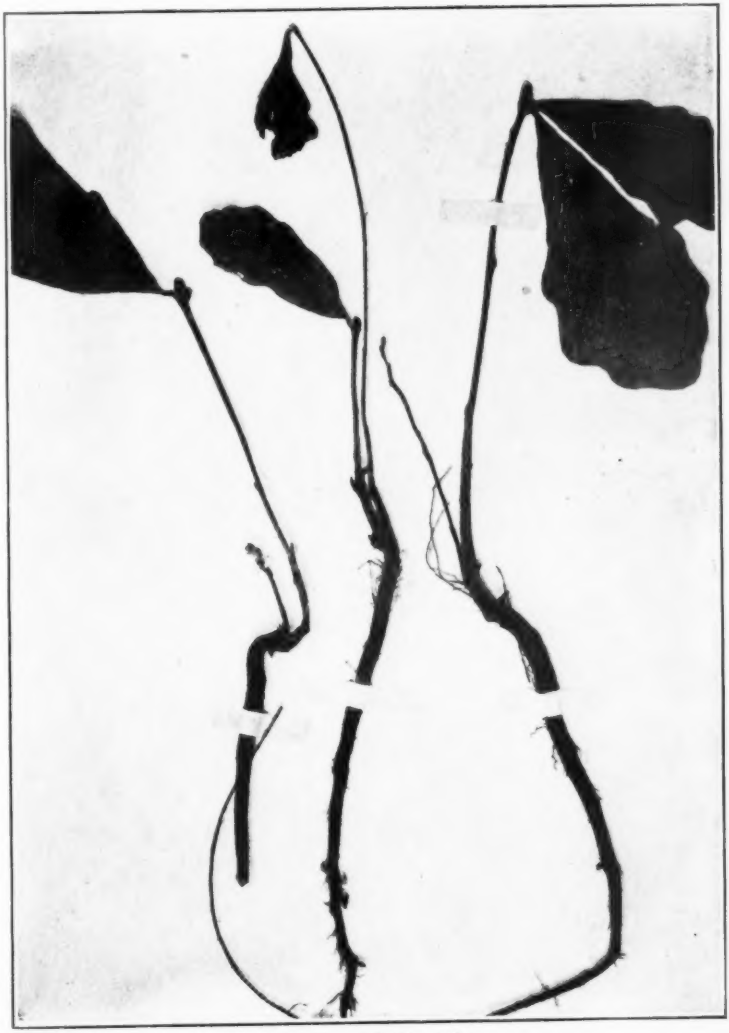
And a little further on, she says:

"The formation of assimilating organs in the seedling of a geophilous plant is, however, very greatly limited by the shortness of the growing season and the necessary formation of subterranean organs. Here lies the explanation we are seeking: the reduction of the cotyledons and the formation of a tuber are both adaptations to the geophilous habit. . . . . "

Is it not remarkable that these observations should apply so exactly to *Quercus virginiana*, the oak which shows the strongest tendency[1] to the geophilous habit?

In the Botanical Gazette, Vol. XXXVII, p. 62, I published a drawing of an acorn *Quercus Prinus L.* from which three healthy young plants were sprouting. Most of the acorns from the same tree were also multiseeded. There is in Chapel Hill,

[1] All oaks show a slight tendency towards the geophilous habit in the concentration of the early growth in the root, and Englemann mentions the occasional fusion of the cotyledons in *Quercus pungens*, a shrub of dry regions in the West.



Seedlings of White Oak.

N. C., a magnificent tree of *Quercus alba L.* that shows the same peculiarity. Through a number of years I have watched this tree and there are always a large proportion of its acorns that contain two or three young plants. A further point of interest is that the seedlings from these acorns show a strong tendency to put out branches from the axils of the cotyledons. Three of these young plants, all from multiseeded acorns, are shown in plate III. Each has an additional shoot springing from one cotyledonary bud. Usually only one of the two auxillary buds grows, but there is frequently an effort to put out both buds, the second rarely reaching more than a centimeter in length. As a result of this combination of peculiarities it might happen that if there were three embryos and each produced a bud from its cotyledon, as many as nine shoots would appear above the ground from a single acorn. It is probable, however, that this never occurs, and the largest number I have ever seen is five, consisting of three primary shoots and a bud from one cotyledon of two of them.

There is evidently a correlation between this tendency to multiseeded acorns and the formation of buds at the cotyledons, both being the result of an unusual tendency towards fecundity or proliferation that is inherent in the nature of this tree.

Among the three seedlings shown in the photograph, the one to the right exhibits a still further peculiarity. Several latteral roots have appeared on the hipicotyl—a most unusual occurrence for the oak. These roots may be seen coming from the stem as far up as three-quarters of a centimeter above the attachment of the cotyledons.

Chapel Hill, N. C.

AN EXPERIMENTAL PROOF OF INVERTED RETINAL IMAGES*

By A. H. Patterson

It is usually somewhat mystifying to be told that all upright objects, such as trees, men walking, etc., form inverted or upside-down images on the retina of the eye. However, it is easy to construct a simple bit of apparatus which will prove the point in question. But first we must understand clearly one or two principles of the action of light rays.

Take a sheet of cardboard *S* and pierce in it a small hole about one-tenth of an inch in diameter. In front of it place a lighted candle, and behind it a cardboard screen *S'*. On this latter screen will be seen an inverted image of the candle —a so-called "pin-hole image." Now place the candle quite close to the screen *S* and let its light shine through the small hole upon the screen *S'*. Then take a third cardboard screen *S''*, from the middle of which is cut a hole 1 inch in diameter, and place it between the two screens *S* and *S'*. The divergent pencil of rays coming through the hole in *S* and the inch hole in *S''* will illuminate a circular area on the screen *S'* slightly more than an inch in diameter. Take some object, say a small cross, and hold it upright before the hole in *S''*. It will cast a shadow in the circular lighted area on screen *S'*, and this shadow will be upright. There is no reason why it should be otherwise. If, now, a double convex lens is held behind the hole in screen *S''*, the size of the lighted area and the cruciform shadow on *S'* will be altered, but the shadow will still be upright.

Now for our experiment. Construct of thin pieces of wood a frame like that shown in the drawing. The distance *AB* is about 7 inches; the hole *C* is about one-tenth of an inch in diameter, and *DE* is piece of white letter paper about 4 inches square, pasted over the wooden upright at the left. At *F* a tiny hole is pierced through the paper with an

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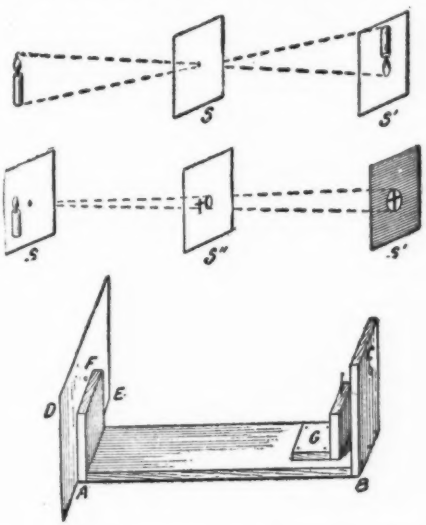
ordinary pin. Now stick a pin upright in the block G and adjust the position of the block so that the head of the pin is exactly in line between the holes C and F, and three-fourths of an inch from the hole C. Fix the block G in this position. This completes our apparatus. Placing the eye close to the hole C and looking through hole F at the sky, we see a lighted



circular area with the shadow of the pinhead in its center, but *this shadow is inverted.* We are ready to declare that the pin is upside down, for it certainly looks so. When we reflect a moment, however, we see that we have now exactly the same arrangement as in the middle diagram. The hole F represents the hole in the screen S, the pinhead represents the cross, the pupil of the eye represents the hole in screen S'', and the retina of the eye takes the place of screen S' and receives the upright shadow of the pinhead upon it. The crystalline lens of the eye acts precisely like the lens in Fig. 2, altering the size of the retinal shadow, but not its upright

position. This upright shadow on the retina, however, makes us think that the object throwing it is inverted, for the shadow certainly "looks" inverted to us. But we know that the object throwing the shadow is upright, and it follows in consequence that the retinal images of upright objects are inverted. In using this apparatus the eye must not be focussed on the pin, or the hole *F*, but on something distant, like the clouds or the twigs of trees between the observer and the sky.

Chapel Hill, N. C.